Technical Paper 101

DEPARTMENT OF THE INTERIOR
BUREAU OF MINES
JOSEPH A. HOLMES, DIRECTOR

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PERMISSIBLE EXPLOSION-PROOF ELECTRIC MOTORS FOR MINES; CONDITIONS AND REQUIREMENTS FOR TEST AND APPROVAL

BY

H. H. CLARK

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PERMISSIBLE EXPLOSION-PROOF ELECTRIC MOTORS FOR MINES; CONDITIONS AND REQUIREMENTS FOR TEST AND APPROVAL.

By H. H. Clark.

GENERAL STATEMENT.

PURPOSE OF PAPER.

Among its investigations dealing with the means of lessening such dangers as attend the use of electricity in the mining industries, the Bureau of Mines has undertaken one that has for its purpose the establishment of permissible explosion-proof motors for use in places where an electric spark or flash might ignite inflammable gases or dusts. This paper mentions the details of construction that the bureau considers essential for satisfactory service and describes tests of an explosion-proof mining-machine motor and accessories approved by the bureau.

DEFINITION OF EXPLOSION PROOF.

The Bureau of Mines has applied the term "explosion proof" to motors constructed so as to prevent the ignition of gas surrounding the motor by any sparks, flashes, or explosions of gas or of gas and coal dust that may occur within the motor casing.

PRELIMINARY WORK.

Before it undertook to establish a list of permissible motors the bureau made a large number of preliminary tests, the results of which are published in its Bulletin 46.[a] No motors were approved as a result of this preliminary investigation, for none of the motors tested was considered to possess the characteristics of permissibility. As a direct result of these preliminary tests, however, the bureau decided to make tests to establish a list of permissible explosion-proof motors, and issued its Schedule 2, "Fees for Testing Explosion-Proof Motors." This schedule gave the general conditions under which motors could

[a] Clark, H. H., An investigation of explosion-proof motors: Bull. 46, Bureau of Mines, 1914, 44 pp.

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be submitted for test and the fees to be charged for making such tests. This paper sets forth more fully than Schedule 2, the details that the bureau considers essential to satisfactory explosion-proof motor construction.

DEFINITION OF PERMISSIBLE.

The Bureau of Mines considers a motor to be permissible when it is the same in all respects as the sample motor that passed certain tests made by the bureau and when it is installed and used in accordance with the conditions prescribed by the bureau.

REQUIREMENTS FOR APPROVAL OF MOTORS.

IDENTIFICATION OF MOTORS.

Before the Bureau of Mines approves any motor as permissible there must be on file with the bureau the following data to be used for the identification of the motor and to be mentioned in the published approval of the motor.

1. The complete rating of the motor in accordance with the 1914 standardization rules of the American Institute of Electrical Engineers.

2. Dimension drawings that show clearly—

a. The size and general appearance of the motor casing.

b. The size and details of the protective devices and their relative arrangement on the motor casing.

c. The relative arrangement of parts within the motor casing.

d. The same information in regard to the starting rheostat as is requested for the motor.

e. Any other drawings necessary to identify or explain any feature that was considered in the approval of the motor or its accessories.

DESIGN AND CONSTRUCTION.

The design and construction of permissible explosion-proof motors and their accessories must be especially durable. This requirement will be applied consistently to all the details of the machine, as well as to its principal parts, in order to be assured that, under the severe conditions imposed by mining service, the explosion-proof qualities of the equipment will remain unimpaired.

The protective devices used with permissible explosion-proof motors must not only be capable of preventing the passage of flames from the interior to the exterior of the motor casing, but such devices must also possess sufficient mechanical strength to insure against the accidental destruction of their protective qualities. If there are moving parts in connection with such devices, these parts should be so designed that there can be no interference with their movement.

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STARTING RHEOSTATS.

Starting rheostats and other necessary equipment that may cause an ignition of gas must be protected as adequately as the motor itself. The casings of starting rheostats must be explosion proof. The resistances and contacts of the starting rheostats used with portable motors of not more than 50 horsepower capacity should be inclosed in the same box, unless inclosed in separate boxes connected by approved piping through which all leads are carried. All leads entering the explosion-proof casing of a starting rheostat should pass through the casing in the form of properly protected insulated studs of approved design. The use of rubber bushings will not be approved because the bushing may become displaced and thus destroy the explosion-proof quality of the casing. The casing of the starting rheostat should be mounted on the motor casing, if possible, and the intercommunicating openings for the passage of leads should be made large in order to prevent the rise of pressure that always attends the propagation of an explosion through a small hole from one compartment to another.

If it is not possible to mount the starting rheostat on the motor frame, all leads connecting the starter with the motor should be carried in rigid metallic conduit.

Unless means for opening the circuit both automatically and by hand are provided in a separate explosion-proof casing, they should be incorporated in the design of the starting rheostat. If the starting rheostat is mounted on the frame of the motor, provision should be made for entirely disconnecting the electric circuit from the starting rheostat.

MOTOR CASING.

All joints in the casing of a motor or of any of its accessories must be metal to metal joints with faces not less than 1 inch wide, and if the pressure developed in the motor casing by explosions can exceed 50 pounds per square inch the faces must be not less than 1½ inches wide. All bolt holes in casings must be bottomed or so arranged that the accidental omission of a bolt will not give an opening through the casing. All openings in the motor casing other than those provided with protective devices by the manufacturers must be tightly closed. It is desirable that such openings be as few as possible. There should be no exposed terminals or contacts outside the motor casing. If there are glass-covered openings in the casing of a motor, the glass should be of ample thickness and should be protected by strong metal covers that close automatically unless held open by hand. Armature bearings must be so designed that under no circumstances can an explosion be propagated from the interior of the motor casing around the armature shaft or through the oil wells.

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CABLE REEL AND TRAILING CABLE.

If there are any sliding or rubbing contacts in connection with the cable reel, such contacts should be provided with explosion-proof protection, and any plug connections should be constructed so that they will be explosion proof. At the point where trailing cables enter the frames of portable motors, the cable should be protected with suitable armor or flexible metallic conduit, securely fastened to the frame of the motor, and of a sufficient flexibility to prevent short bends from occurring in the cable. The cable should not be fastened to this armor, but there should be provided inside the frame of the motor, an insulated clamp of approved design for securely fastening the cable and taking all mechanical strains that may be put upon it.

TESTS.

In testing a motor to establish its permissibility, the motor casing will be filled and surrounded with the most explosive mixture of Pittsburgh natural gas and air. The motor will then be operated at its rated speed and the mixture within the casing ignited by a spark plug, by a spark from the motor brushes, or by any other means that simulates the conditions of actual practice.

Similar tests will also be made with greater and with less amounts of gas in the explosive mixture and with coal dust sifted into the motor casing or into the protective devices.

Tests will also be made to determine the point of ignition that gives the greatest pressure, and tests will be made by igniting from such a point. Not less than 50 tests of all kinds will be made, and more than that number may be made if, in the opinion of the bureau's engineers, more tests are necessary to prove the permissibility of the motor. In order for a motor to pass these tests, it shall in none of them cause an ignition of the gas surrounding the motor or discharge flames from any part of the motor casing. Neither shall the motor develop dangerous afterburning [a] or excessive pressure in the casing of the motor or its starting rheostat.

Even after having passed the tests just described, motors or equipments will not be regarded as permissible if used under any of the conditions outlined below:

If used without the caution plate mentioned hereafter.

If used with openings in the motor casings other than those openings provided with protective devices by the manufacturer.

[a] The term "afterburning" as used in this report is applied to the combustion, immediately after an explosion within an explosion-proof casing, of a gaseous mixture that was not within the casing at the time of the explosion, but was drawn in subsequently while the products of the explosion were cooling.

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This condition refers to all openings but especially to removable covers.

If the motor or equipment when in operation is not complete with all of the parts considered in the approval of the motor or equipment.

CAUTION AND APPROVAL PLATES.

As part of the protection of a permissible motor, the manufacturer shall be required to attach to the motor frame a metal plate inscribed as follows:

> CAUTION.
>
> The permissibility of this motor depends upon the absence of any openings in the casing other than those provided with protective devices by the manufacturer.
>
> Cover plates should be screwed on tight and the casing frequently inspected for improper openings.

The manufacturer shall be permitted to attach to the motor frame a plate inscribed as follows:

> PERMISSIBLE EXPLOSION-PROOF MOTOR.
>
> SEAL.
>
> Approval No. ———.
>
> Issued to the ———————— Company.

The size, material, and design of both caution and approval plates shall meet with the approval of the bureau.

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The caution and statement of approval may be combined upon a single plate, a suggested form for which is shown below:

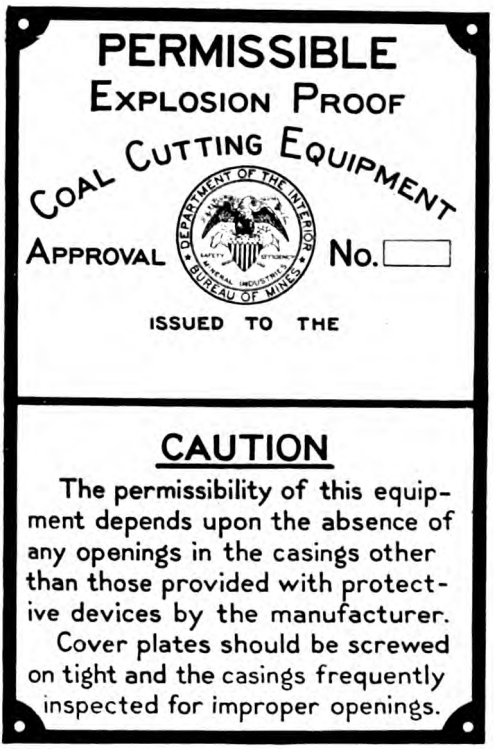
PERMISSIBLE
EXPLOSION PROOF
COAL CUTTING EQUIPMENT
APPROVAL
DEPARTMENT OF THE INTERIOR
BUREAU OF MINES
No.
ISSUED TO THE
CAUTION
The permissibility of this equipment depends upon the absence of any openings in the casings other than those provided with protective devices by the manufacturer.
Cover plates should be screwed on tight and the casings frequently inspected for improper openings.

FIGURE 1.—Suggested approval plate.

NOTIFICATION OF MANUFACTURER.

As soon as the bureau's engineers are satisfied that a motor is permissible for use where gas may occasionally be present in explosive proportions, the manufacturer shall be notified to that effect.

As soon as a manufacturer receives formal notification that his motor has passed the tests prescribed by the bureau, he shall be free to advertise such motor as permissible and may attach approval plates to such motors.

DRAWING LIST OF APPROVED MOTORS.

Since the safety of an explosion-proof motor depends largely upon its construction, the approval of a motor must identify the details of construction upon which the approval is based. This identification will be accomplished by reference to a list of drawings and photographs that describe in detail such parts as directly or indirectly affect the safety of the motor or any of its accessories. Each

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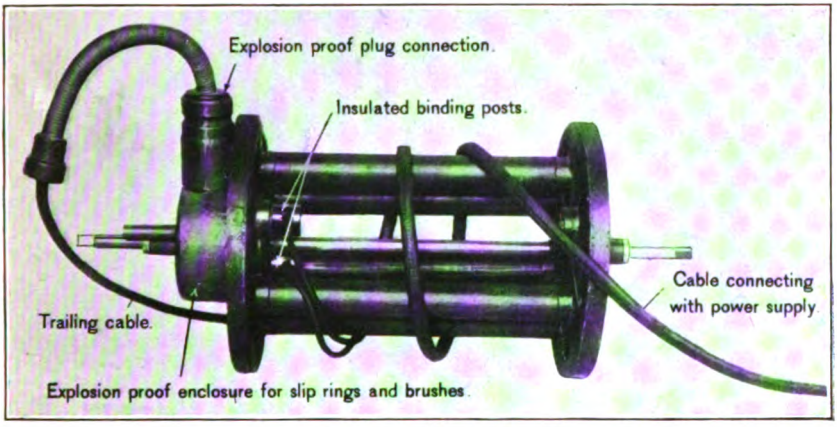
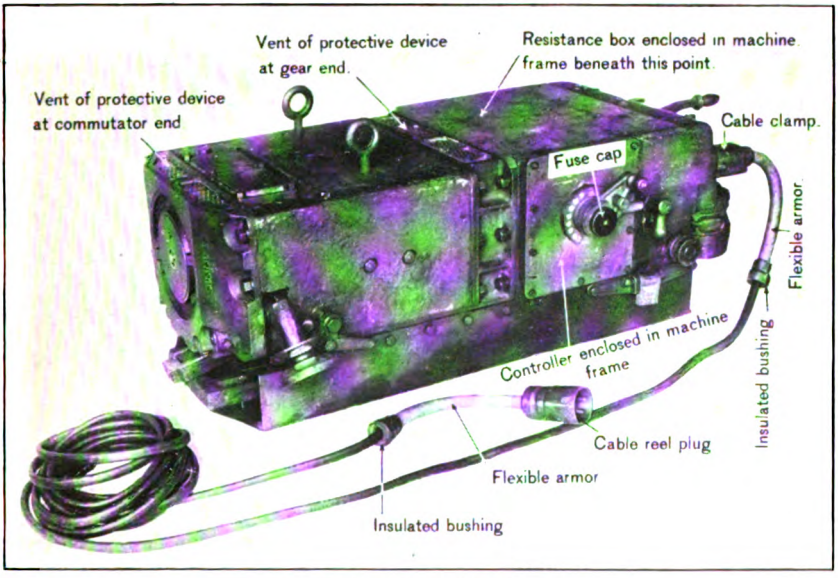

Explosion proof plug connection.
Insulated binding posts.
Cable connecting with power supply
Trailing cable.
Explosion proof enclosure for slip rings and brushes.

A. CABLE REEL.



B. MOTOR AND STARTING BOX.

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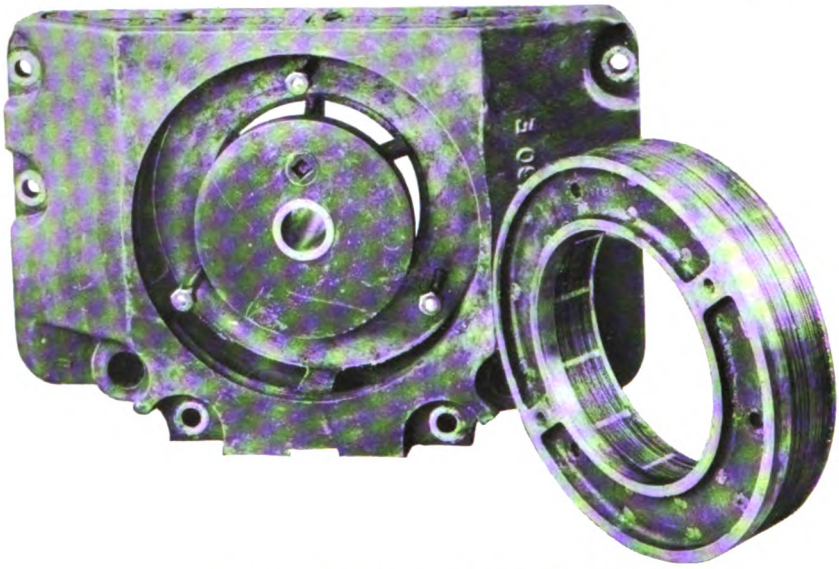
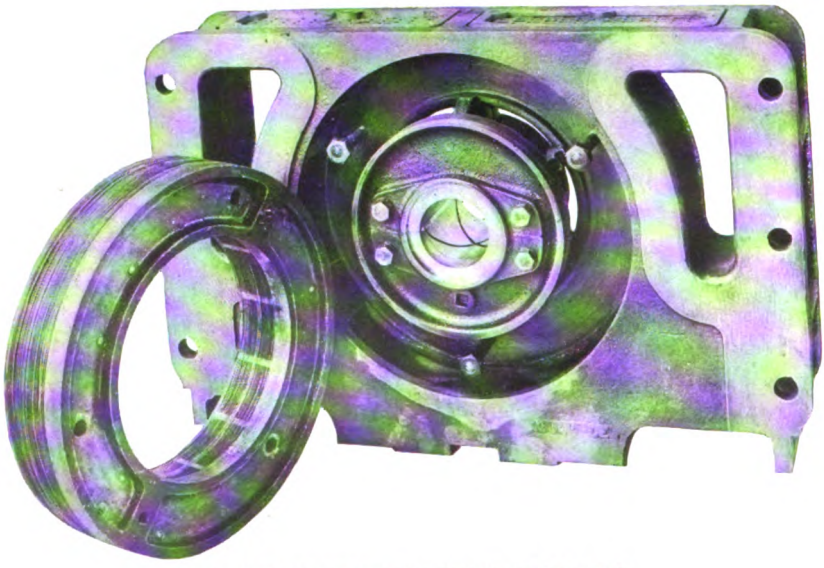


A. VIEW OF PROTECTIVE DEVICE AT COMMUTATOR END.



B. VIEW OF PROTECTIVE DEVICE AT GEAR END.

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list of drawings will be given a number to facilitate reference. A copy of each drawing will be filed with the Bureau of Mines, although only a few of the drawings may be reproduced in the description of the motor that is published by the bureau.

SCOPE OF APPROVAL.

The bureau's approval of any motor shall be construed as applying to all motors of that specific type, class, form, and rating, made by the same manufacturer, that have the same construction in the details directly or indirectly affecting the safety of the motor, but to no other motors.

Manufacturers shall, before claiming the bureau's approval for any modification of an approved motor, submit to the bureau drawings that shall show the extent and nature of such modifications, in order that the bureau may decide whether or not it will be necessary to test the remodeled motor before approving it. Each approval of a permissible motor will be given a serial number.

WITHDRAWAL OF APPROVAL.

The bureau reserves the right to rescind for cause, at any time, any approval granted under the conditions herein set forth.

PRECAUTIONS.

It is obviously futile to protect the motor and neglect to safeguard any spark-producing accessory apparatus, such as rheostats, switches, and fuses. It is equally unavailing to protect all of the apparatus if, within the limits made dangerous by the presence of gas, there are used in connection with the electrical equipment uninsulated wires or wires not installed upon suitable insulators and in a first-class manner. The protection of the electrical system in gaseous places must be made consistently complete.

MOTOR ALREADY APPROVED.

Approval No. 100 has been issued to the Sullivan Machinery Co. covering an explosion-proof coal-cutting equipment, consisting of the following parts:

One explosion-proof electric motor; one explosion-proof starting rheostat and fuse; one explosion-proof cable reel.

The use of all of these parts is considered to be essential to the permissibility of the equipment.

Plate I, *B* shows the motor and starting box completely assembled. Plate I, *A* shows the cable reel completely assembled with the explosion-proof plug and covering for the slip rings. Plate II shows the protective devices which are mounted at each end of the motor casing.

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Drawing list No. 100 covers the details of construction of the complete equipment. The numbers and titles of the drawings and photographs included in this drawing list are as follows:

Drawings and photographs listed.

Drawing No.	Part described.
CE1949	Cable-reel assembly.
CE2099	Rear motor head.
CE2107	Main frame.
CE2110	Assembly of controller with fuse plug.
CE2112	Special binding posts and studs.
CE2132	Sectional machine assembly.
CE2174	Refillable fuse.
M887167	Details of protective device.
T890184	Magnet frame.
P893160	Commutator end motor head.

Photograph No.	
5989	Gear end of machine, showing flanges, resistance boxes, conductor passages, and special binding posts.
5990	Commutator end of motor, showing flanges, cover plate, and stud bolts.
5991	Gear end of motor, showing flanges, and conductor passages.
5992	Side view of gear end of machine, showing interior of starting box.
5993	Cable-reel exploded view.
5994	Cable reel assembled.
5995	Equipment complete without cable reel.

MOTOR.

The motor is rated CY-24-B—30 H. P.—30—250—1130, and is a compound-wound machine designed to deliver 30 horsepower for 1 hour without exceeding a temperature rise of 75° C.

The protective devices (Pl. II) used on the motor are of the plate type and are protected from mechanical injury by strong noncorrosive metallic gratings. There are no openings in the motor frame, except one over the commutator, which is closed by a solid cover bolted to the frame.

STARTING RHEOSTAT AND FUSE.

The casing of the starting rheostat is made part of the machine frame. The controller plate is mounted on one side of the machine and the resistances on the other. They are, however, in the same box, and all leads between them are completely inclosed and protected. There is a cover plate over the resistances and one over the controller. Both cover plates are made with broad flanges and are fastened to the machine frame with stud bolts. The electrical connection with the trailing cable passes through the casing of the rheostat in the form of studs insulated with fiber washers and bushings.

There is mounted in the shaft of the controller a totally inclosed refillable fuse, having practically the dimensions specified for 250-

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volt, 100-ampere fuses by the National Electric Code. The fuse is so placed that it is accessible from outside the machine without removing any covers, but the controller handle must be in the "off" position before the fuse can be removed, and removal of the fuse locks the controller handle in the "off" position.

CABLE REEL.

The cable that connects the cable reel to the power supply is permanently connected to slip rings which are inclosed in an explosion-proof casing. The cable that connects the cable reel to the motor is provided with a plug which connects with the slip ring brushes in such a manner that arcs can not get outside the casing if the plug should be withdrawn while the current is flowing.

TRAILING CABLE.

The trailing cable is clamped to the frame of the machine by an insulated clamp that sustains any strains that might otherwise come on the insulated binding posts by means of which electrical connection is made to the interior of the controller casing. These binding posts are specially designed to prevent the working loose of stranded conductors and are protected by a metallic shield.

Where the trailing cable enters the machine frame and also where it is attached to the cable reel plug the cable is protected by a flexible steel armor that bends easily to a minimum radius beyond which it will not go. This armor is designed to prevent the excessive wear that usually occurs where cables of this sort enter metallic frames.

COMPLETE EQUIPMENT.

The complete equipment (Pl. I) is built in accordance with the bureau's requirements and recommendations as set forth in the preceding pages. All wires are inclosed in explosion-proof casings from the point where the connection to the trailing cable enters the casing of the starting rheostat.

All bolt holes are bottomed or stud bolts are used, so that the omission of a bolt does not leave an opening through the explosion-proof casing.

TESTS.

The tests enumerated below were made at the Pittsburgh experiment station of the Bureau of Mines with the motor, starting rheostat, and cable reel covered by approval No. 100.

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Test of equipment.

TESTS OF MOTOR AND STARTING RHEOSTAT.

Number of tests.	Percentage of gas.	Means of ignition.	Cover condition.	Puncture.[a]	External flames.	Dangerous after-burning.
13	8.6	Spark plug	Seated	No	No	No.
13	8.6	do	Raised	No	No	No.
10	8.6, dust	do	do	No	No	No.
4	8.6, dust	do	do	No	No	No.
10	7.0, dust	do	do	No	No	No.
10	7.0, dust	do	do	No	No	No.

TESTS OF CABLE REEL.

1	8.6	Spark plug		No	No	No.
9	8.6, dust	do		No	No	No.
5	7.0, dust	do		No	No	No.
10	7.0, dust	do		No	No	No.

[a] The term "puncture" means the ignition of gaseous mixtures surrounding a motor casing by flames discharged from it.

The following maximum pressures were obtained:

One hundred and twenty-six pounds per square inch in the casing of the starting rheostat, 74.6 pounds per square inch in the motor casing, and 35 pounds per square inch in the slip-ring compartment of the cable reel.

TESTS OF FUSE.

The fuse was tested 15 times by connecting it across the bus-bar of a 200-kilowatt, 225-volt, direct-current generator in series with a resistance equivalent to a circuit of No. 4/0 B. & S. gage wire 530 feet in length (one way). The fuse opened the circuit promptly, with practically no noise, and absolutely no evidence of flames or sparks.

CONCLUSIONS.

The test proved that the protection of the motor, starting rheostat, and cable reel was adequate at the time of testing. A factor of safety was produced by requiring changes in construction that reduced the maximum pressure from 126 pounds per square inch to less than 50 pounds per square inch in any part. The mechanical inspection of the machine showed that its construction conformed to all of the requirements set forth in the previous pages of this report. It is therefore considered that with reasonable care the equipment can be maintained permanently in an explosion-proof condition. The equipment has therefore been approved by the bureau as permissible for use in gaseous mines.

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PUBLICATIONS ON MINE ACCIDENTS AND METHODS OF COAL MINING.

Limited editions of the following Bureau of Mines publications are temporarily available for free distribution. Requests for all publications can not be granted, and applicants should select only those publications that are of especial interest to them. All requests for publications should be addressed to the Director, Bureau of Mines, Washington, D. C.

BULLETIN 10. The use of permissible explosives, by J. J. Rutledge and Clarence Hall. 1912. 34 pp., 5 pls., 4 figs.

BULLETIN 17. A primer on explosives for coal miners, by C. E. Munroe and Clarence Hall. 61 pp., 10 pls., 12 figs. Reprint of United States Geological Survey Bulletin 423.

BULLETIN 20. The explosibility of coal dust, by G. S. Rice, with chapters by J. C. W. Frazer, Axel Larsen, Frank Haas, and Carl Scholz. 204 pp., 14 pls., 28 figs.

BULLETIN 42. The sampling and examination of mine gases and natural gas, by G. A Burrell and F. M. Seibert. 1913. 116 pp., 2 pls., 23 figs.

BULLETIN 45. Sand available for filling mine workings in the Northern Anthracite Coal Basin of Pennsylvania, by N. H. Darton. 1913. 33 pp., 8 pls., 5 figs.

BULLETIN 46. An investigation of explosion-proof mine motors, by H. H. Clark. 1912. 44 pp., 6 pls., 14 figs.

BULLETIN 48. The selection of explosives used in engineering and mining operations, by Clarence Hall and S. P. Howell. 1913. 50 pp., 3 pls., 7 figs.

BULLETIN 50. A laboratory study of the inflammability of coal dust, by J. C. W. Frazer, E. J. Hoffman, and L. A. Scholl, jr. 1913. 60 pp., 95 figs.

BULLETIN 52. Ignition of mine gases by the filaments of incandescent electric lamps, by H. H. Clark and L. C. Ilsley. 1913. 31 pp., 6 pls., 2 figs.

BULLETIN 56. First series of coal-dust explosion tests in the experimental mine, by G. S. Rice, L. M. Jones, J. K. Clement, and W. L. Egy. 1913. 115 pp., 12 pls., 28 figs.

BULLETIN 60. Hydraulic mine filling; its use in the Pennsylvania anthracite fields; a preliminary report, by Charles Enzian. 1913. 77 pp., 3 pls., 12 figs.

BULLETIN 62. National mine-rescue and first-aid conference, Pittsburgh, Pa., September 23–26, 1912, by H. M. Wilson. 1913. 74 pp.

BULLETIN 68. Electric switches for use in gaseous mines, by H. H. Clark and R. W. Crocker. 1913. 40 pp., 6 pls.

BULLETIN 69. Coal-mine accidents in the United States and foreign countries, compiled by F. W. Horton. 1913. 102 pp., 3 pls., 40 figs.

TECHNICAL PAPER 4. The electrical section of the Bureau of Mines, its purpose and equipment, by H. H. Clark. 1911. 12 pp.

TECHNICAL PAPER 6. The rate of burning of fuse as influenced by temperature and pressure, by W. O. Snelling and W. C. Cope. 1912. 28 pp.

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